The Virtual Sand Table

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Abstract

The Virtual Sand Table (VST) is a series of software tools designed to help commanders better manage their battle space on a highly digitized battlefield identified by the U.S. Army as its near-team vision of future battle. The VST will assist commanders and their staffs in conducting the current battle and in preparing for the future battle. The VST provides an innovative way to visualize the battlefield from a unique and realistic perspective.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

LIST OF FIGURES

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1. INTRODUCTION

The Virtual Sand Table (VST) is a series of software tools designed to help commanders better manage their battle space on the highly digitized battlefield, identified by the U.S. Army as its near-term vision of future battle. The VST can aid commanders and their staffs with their management of the current battle and with preparation for the future battle. This assistance is provided through an innovative three-dimensional (3D) visualization of the battlefield and by interaction with the display by means of voice commands and a 3D pointing device. As a result, commanders are able to stand on a "virtual hilltop" and watch the current battle develop, reminiscent of the way battles were fought more than a hundred years ago.

A demonstration of VST concepts, described in this report, was presented at the Army Experiment III held in Washington, DC, 14-16 October 1996.

2. GENERAL

One goal of the VST project was to provide the commander with a virtual environment (VE) command tool that modified the paradigm used by existing VE tools. Typically, VE command tools allow the commander a limited perspective of the battlefield, confining the view to an individual vehicle or ground position. While this view is compelling, it does not allow commanders to observe the entire battle space or command the entirety of their forces.

A second, but more important, goal for the development of the VST was to provide the commander an intuitive way of interfacing with simulations that can assist field commanders in conducting course-of-action (COA) development and analysis. Thus, the goal of the VST was not to simply draw a picture of the battlefield but to visualize information pertaining to the battle. This reflects the opinion of the U.S. Army Training and Doctrine Command (TRADOC) that, "Technology alone cannot provide the commander with a full visualization of the battlefield. Technology must be used together with the commander's judgment, wisdom, experience, and intuitive sense to enhance the visualization of the battlefield" [1].

The VST was developed to demonstrate a means by which a commander may view a chosen subset of available information that meets his planning needs. This concept does not eliminate the need for the tools that generate this information but, instead, manages its presentation and allows for commander interaction. Though similar efforts have been conducted by other research organizations, the VST has unique capabilities as discussed in the following sections (see Appendix A).

2.1 System Overview

The VST is comprised of two software programs: a modified version of NPSNET and an interactive voice recognition system, VSTLink. NPSNET is a virtual simulation developed at the Naval Postgraduate School (NPS). A number of unique features that support the goals previously discussed were incorporated into NPSNET by in-house modification of the original source code. This modified version of NPSNET is referred to as the VST. VSTLink is an in-house software program, which, in conjunction with the licensed speech-recognition software, BBN Hark, parses and interprets voice commands and acts as a UNIX Transmission Control Protocol/Internet Protocol (TCP/IP) socket server for NPSNET. A benefit of maintaining VSTLink separately from the VST allows for the substitution of alternative interfaces, making the VST interface independent.

The physical construction of the VST consists of a large, rear-projection, horizontal display; three smaller, flat-panel displays; a noise-canceling microphone; and a pointing device, such as a stylus or data glove (see Figure 1 and Appendix B). The main view of the battle space is presented on the large display. The smaller monitors are used to display

output from other VST integrated programs, such as the Modular Semi-Automated Forces (ModSAF) simulation, the Virtual Geographic Information System (VGIS), and the Combat Information Processor (CIP). The user speaks commands into a noise-canceling microphone and moves a 3D cursor with a pointing device.

Figure 1. Virtual Sand Table.

2.2 Hardware Suite

A key component of the VST is a large, horizontal, rear-projection display unit. Requirements for the display include the restriction that the unit must fit through a standard doorway and be the height of a standard table. In order to comply with these requirements, the selected vendor, AmPro Corporation of Melbourne, Florida, developed a design to multiply fold the light path for the projector. Such a design contrasts with other projection systems that require long, linear light throws, which would meet the specified size requirements (see Appendix C and Figure C-1).

The VST is capable of displaying its visualizations in stereo. Liquid crystal display (LCD) shutter glasses and associated emitters are used to view rapidly alternating left and right eye images which the user's mind fuses together to create the illusion of three dimensions.

The VST allows a user to interact with the software by using voice commands and physical pointing devices. BBN Hark's Developer Toolkit and Workstation Recognizer were selected for the voice recognition system and are run on a Silicon Graphics Incorporated (SGI) Indigo2 High Impact computer. Either a stylus or data glove can be

used as the pointing device. The stylus interacts directly with the Polhemus tracking system. The input from the data glove is interpreted first by the GesturePlus Computer System and then broadcast across a serial connection to the computer running the VST.

Hardware requirements of the VST necessitate multiple computer systems to run the VST software, VSTLink, and any VST integrated programs used. The VST requires a computer system with high-end graphics capability, such as an Onyx RealityEngine2 system.

2.3 Distributed Interactive Simulation

Because early development of virtual simulators, designed to train soldiers in their individual jobs, often created disparate systems, the later goal of training teams of soldiers generated a requirement to network military simulations together. The Distributed Interactive Simulation (DIS) protocol was developed to meet this requirement. This protocol enables any compliant simulation to communicate and interact with other compliant simulations by means of defined and standardized protocol data units (PDUs) that pass information such as a simulation entity's state or when an entity has fired its weapon [2]. DIS is defined as an "infrastructure for linking simulations of various types at multiple locations to create realistic, complex, virtual 'worlds' for the simulations of highly interactive activities. This infrastructure brings together systems built for separate purposes, technologies from different eras, products from various vendors, and platforms from various services and permits them to interoperate. DIS exercises are intended to support a mixture of virtual entities (human-in-the-loop simulators), live entities (operational platforms and test and evaluations systems), and constructive entities (wargames and other automated simulations) [3].

2.4 NPSNET

NPSNET was developed as a low-cost, real-time, DIS-compliant, 3D simulation [4]. The program executes on SGI IRIS workstations. Since its creation, the program has been used as a platform to conduct research in graphical techniques and proof of concept for methods of interacting in real-time, virtual environment, simulations. The program was written by students at NPS and is available to government agencies and industry.

NPSNET has evolved over time and in its current version, NPSNET IV, is written in C++ with SGI's Performer as the graphics application program interface (API). The program is compliant with the DIS 2.04 standard.

NPSNET IV can be reconfigured to operate in various modes. In stealth mode, the user can fly, undetected by other participants, through a virtual environment, examining a distributed simulation from any viewpoint (see Section 2.7). The user can also interact with other players or simulations by selecting a specific platform, such as a tank or helicopter, to operate. Once a platform is chosen, NPSNET reconfigures to behave as that vehicle. The user can use various peripheral devices to navigate through the virtual environment. Such devices can include a spaceball, flight control stick and throttle, positional tracking devices, or the mouse and keyboard.

2.5 Stylus/Tracking

The VST allows the user to interact with the program via a graphical 3D cursor, hand-held stylus (receiver and pointing device), transmitter, and tracker unit. The 3D cursor's movement in the projection table's display corresponds to the movement of the stylus. The stylus is designed to receive electromagnetic signals generated by a transmitter fixed to the front of the projection table. Both the stylus and the transmitter are connected to each other via a Polhemus tracker unit. Based on the strength of the electromagnetic signal received by the stylus, the tracker unit is able to determine the coordinate location of the stylus relative

to the fixed transmitter. By knowing the physical location of the transmitter relative to the projection table's display screen, it is possible to use the relative coordinate location of the stylus to update the horizontal, or X-Y, plane position of the 3D cursor on the display. The 3D cursor's elevation, or Z coordinate, is set to that of the terrain at the location defined by the X-Y coordinates. The transmitter has an effective range of 30 inches. Note that this short range does not allow for accurate control of the 3D cursor over the entire display of the projection table.

The 3D cursor is used in conjunction with voice commands to perform interactive tasks that include: tethering to a vehicle to provide an auxiliary view (on a separate display channel) from the selected vehicle's position, and creating persistent objects such as phase lines. See section 2.8 for a more detailed explanation of the 3D cursor.

2.6 Speech Recognition

The VST uses the BBN Hark, commercially available speech recognition system. Hark is a real-time, continuous speech recognition software package that does not require training by each user making the system largely speaker independent. This package consists of two basic tools: the Prototyper and the Recognizer. The Prototyper provides the utilities to create a grammar for a particular application. The grammar is specified to resemble the Bakus-Nauer form as described by Cohen [5]. The Recognizer is a run-time process that attempts to match spoken words with sentences in the predefined grammar. In response to a spoken phrase, an application program, which incorporates the Hark system, first calls a recognition function. If the phrase matches a sentence in the grammar, a character string, or code, representing that entry code is returned. If the phrase is not in the established grammar, a "not-recognized" code is returned. The application program determines how to proceed based on the returned [6,7].

VSTLink is the in-house developed application that the VST uses to interpret the output from Hark. There are five basic categories of speech commands: map control, tethering, graphics, heads-up-display (HUD), and miscellaneous (see Appendix D). Map control commands are used to pan, zoom, and rotate the main VST display. Tethering commands are used to either select an entity in the battle space or a location on the terrain. Once selected, the view from this location is presented on a smaller display. Additional tethering commands allow the user to rotate the view. Graphics commands allow the user to draw lines and points on the main display. These lines and points are interpreted as graphic control measures by the VST and any simulations compliant with the Persistent Object Protocol (POP). Heads-up display commands allow the user to turn on and off various informational displays. These displays can show information, such as the location of the user's viewpoint and the cursor. Miscellaneous commands include functions that toggle the stereo view, the display of units, and the display of control measures (see section 2.9).

VSTLink can be thought of as a finite-state machine. Most functions are performed in the *map command* state. In the *map command* state, VSTLink sends appropriate codes to the VST and then waits for the next returned sentence from Hark. In some cases, a spoken phrase triggers a change of state. The following examples illustrate this idea.

When the user indicates with a spoken command that the wish to tether to a vehicle, VSTLink enters the *tethering to vehicle* state. In this state, VSTLink waits for the user to select an entity. After selection, VST sends VSTLink an acknowledgment code, and VSTLink returns to the *map command* state. When the user wants to draw a line, VSTLink enters the *draw line* state and waits for information about the line's location from VST. The user moves the cursor around the terrain, selecting various points along the ground. When the user is done selecting points, the spoken command "DONE" is given. This triggers another change of state, back to *map command*. At this time, the locations of the various points are sent from VST to VSTLink. VSTLink creates a POP data packet and broadcasts this packet on the network. A few seconds later, depending on the complexity of the

4

defined line, the line appears on both the VST display and any other POP-compliant simulation on the network.

Commands that control other software (e.g., VGIS) are easily added to VSTLink. As a convention, all commands that control external programs are preceded with that program's name. For example, the command that moves VGIS's view to a specified point on the map is "VGIS JUMP TO POINT."

2.7 Napoleon Stealth

A stealth vehicle enables a user to navigate the VE without being seen by other entities. The stealth vehicle used in the VST is called the Napoleon Stealth, or Napoleon. This term refers to the VST's unique view, which enables the commander to stand on a virtual hilltop in the manner employed by such historical commanders as Napoleon.

Unmodified NPSNET has a stealth vehicle class. The Napoleon is of this class with a number of important changes. While the NPSNET stealth allows the user to fly freely around the terrain, changing orientation at will, the Napoleon is restricted to looking down at the terrain at a 60° angle from horizontal. This approximates the user's view of a table-high 3D physical model. Movement is restricted to four panning motions: left, right, up, and down, and two zooming motions: in and out. By default, north is at the top of the main display. This view can be rotated in 90° increments. The top of the 3D cursor always indicates the direction north by a green arrow (see Section 2.8). Regardless of the orientation of the terrain, panning motions always move the user's viewpoint in an identical manner.

2.8 Three-Dimensional Cursor

The VST allows the user to interact with the program via a graphical 3D cursor. The cursor's movement on the projection table's display corresponds to the movement of the hand-held stylus discussed in section 2.5. The cursor is used in conjunction with voice commands to perform interactive tasks that include tethering to a vehicle and creating persistent objects.

In an unmodified version of NPSNET, only one vehicle, the driven vehicle, may be controlled by the user. In the VST, the driven vehicle is an instantiation of the Napoleon class as discussed in section 2.7. In order to create a 3D cursor, it was necessary to modify NPSNET to allow for a second user-controlled vehicle. The driven vehicle is the first vehicle in NPSNET's vehicle array list. NPSNET uses the remainder of the list to index received DIS-compliant entities. To include a 3D cursor, NPSNET was modified to add an instantiation of a created Cursor Class to the vehicle list immediately following the driven vehicle.

The Cursor Class is a child of the Vehicle Class. The Cursor Class provides for a user-controllable vehicle that has the ability to (1) select (target) an entity and generate a wireframe bounding-box around the entity to show it is selected, (2) select an entity in conjunction with voice commands to tether or attach to a vehicle, (3) draw persistent objects, and (4) return the cursor's coordinate location.

2.9 Persistent Object Protocol

The POP was developed by LORAL Advanced Distributed Simulations (now Lockheed Advanced Distributed Simulation) as part of their ModSAF simulation for the Army. Like DIS, POP is a broadcast protocol. POP PDUs are received by all simulations listening on a specified UNIX port and participating in the same exercise. The full implementation of POP allows for the creation of control measures, units, and missions. These missions are in the form of tasks (attack, move, occupy position, etc.) that tie units to control measures [8].

As part of his master's program, Samuel Kirby incorporated a subset of POP into NPSNET. When the user of the VST wants to draw a line, VSTLink generates a POP PDU for the described line, which is displayed on any POP-compliant simulation as well as the VST. In the case of the VST, the PDU is interpreted and a corresponding 3D line is rendered. This use of POP was the first rudimentary step in using the VST as an interface to a simulation for future battle planning.

2.10 Units

At low heights above the terrain, the user can identify individual entities, such as tanks, armored personnel carriers, and dismounted infantry by sight. As the user zooms out, at the height at which the individual entities become too small to see, a unit symbol appears over the leader of that unit [9]. The first symbol to appear is for a platoon. As the user zooms farther out, these symbols are replaced by company symbols. These symbols appear over the leader of the unit. Traditional Command, Control, Communications, Computers, and Intelligence (C4I) systems draw symbols over the center of mass of the unit. If entities are destroyed and left behind, the center of mass becomes distorted. The VST method of marking units has two advantages. First, at platoon and company level, the location of the leader is typically a good approximation of the center of mass and thus eliminates time-consuming calculations. Second, higher-level commanders can identify who is in charge. If a unit's current commander dies, the unit's symbol is moved to the entity representing the next in command. Note that while the VST is directed at battalion and brigade commanders, who often fight with platoons and companies, respectively, there is no restriction on adding additional symbology.

The order of battle file, read by the VST during initialization, contains unit hierarchy and succession of command information. This file is based on the bumper numbers of the vehicles in the units. For example, the unit, 3rd Platoon, A Company, might be associated with the bumper numbers A31, A32, A33, and A34. If the bumper numbers appeared in this sequence in the order of battle file, this would indicate that A31 is the platoon leader and that if he died, A32 would take over, and so on. While, for friendly forces, this information is most often known before the start of a battle, the same is not true for enemy forces. Currently, the VST cannot automatically aggregate, deaggregate, or symbolically represent enemy forces.

2.11 Tethering and Attaching

Tethering is the linking of the driven entity's eye point to another entity, known as the lead entity, in the VE. When tethered to a lead vehicle, the driven entity is referred to as the tethered vehicle. The eye point of the tethered vehicle is positioned to view the lead entity from a fixed location and orientation, as if connected to the lead entity by a rigid bar. The tethered vehicle's speed, position, and orientation are controlled by the lead vehicle. Control of the tethered vehicle's view is retained by the tethered vehicle [10].

Attaching is similar to tethering, except that the driven entity has a free range of motion at a fixed distance around the lead entity [10].

The VST has the capability of displaying and controlling a tethered or attached view on a monitor separate from the VST's main display. This capability was implemented for two different computer and display hardware configurations. One configuration uses two computers to run the VST and a modified version, or slave version, of NPSNET, which generates a tethered or attached view. When tethering or attaching to a vehicle in the VST, a PDU is broadcast identifying the lead entity. The slave version receives and interprets this PDU and generates an appropriate view of the lead entity for display. The second configuration uses a single computer with a multichannel option (MCO) and two displays to generate both the VST view and tethered or attached view.

A significant disadvantage of the first configuration is that it requires an additional software program to run on a second computer in order to generate a tethered vehicle's view. While the second configuration eliminates the need for an additional computer and software, it has the disadvantages of displaying both views in lower resolution and requiring the use of a multichannel video splitter, which eliminates the ability to display either view in stereo.

2.12 Stereo View

The VST represents the battle space, the terrain as well as static and dynamic entities, with rendered polygons whose vertices have 3D coordinates. Normally, a single two-dimensional (2D) view of these polygons is generated for display on the projection table. It is possible for the VST to display a stereo view of the simulation by generating two appropriately separated views, which are alternately presented as left- or right-eye views by means of LCD shutter glasses. The use of a stereo view can enhance the user's perception of the simulation in a manner reminiscent of terrain boards built for military classroom use or the ad hoc sand tables used in the field.

Creating a stereo image requires a combination of hardware and software. The first step is to create two views of the simulation in the VST, one for the left eye and one for the right. There are several techniques used to create two eye views, such as two centers of projection, rotation with parallel projection, and shearing with parallel projection. The VST uses shearing as it requires fewer calculations than other methods and automatically accounts for the Z clipping plane [11].

The next step in creating a stereo image is to adjust the viewing plane. When not displaying a stereo view, this plane is set to zero, which is located at the surface of the screen. By setting the location of the viewing plane to be in front of the screen, the object appears to float between the eye and the screen. To make the image appear to be behind the screen, the location of the viewing plane is moved behind the screen. Typically, when a stereo view is used on the VST, the location of the view plane is set to behind the screen. This choice can provide a better stereo image because certain conflicting visual cues that can degrade the view are eliminated. Specifically, if the view plane is located in front of the screen, stereo imagery that intersects the display screen's edges can send conflicting visual cues to the viewer.

To view stereo imagery on the VST, it is necessary for the user to wear LCD shutter glasses, which, when synchronized with the display, allow the user to see only one generated view with one eye at a time. This is accomplished by setting one LCD eye piece to be opaque, or blocked, while the other is transparent, or unblocked. To eliminate flickering of the images, the sync rate of the computer is raised from 60 Hz to 120 Hz or 60 Hz per eye view. The shutter glasses use an infrared (IR) beam emitter, synchronized to the screen refresh rate of the computer, to control which eye of the glasses will be blocked or unblocked.

3. FUTURE DEVELOPMENTS

As of the publication of this report, the first stage of VST development is complete. Additional work could provide greater capability and improvement of the VST. The following are areas in which additional work might be pursued.

3.1 Shrinking Hardware/Cross Platform Portability

Two significant disadvantages of the current implementation of the VST are the high cost of the computer platforms used and that the VST software is not portable to platforms other than SGIs. The chief reason that the software is not portable is the use of the SGI Performer API. A solution would be to rewrite the VST to make use of a cross platform

graphics library, such as OpenGL, which is available for most widely used computer platforms including SGI, Sun, Hewlett Packard, IBM-compatible PCs, and Apple. Rewriting the VST to include cross platform portability would provide users the option of running the VST on typically less costly platforms such as PCs.

3.2 LeatherNet

LeatherNet was developed by the Defense Advanced Research Projects Agency (DARPA) at the Marine Corps Air Ground Combat Center (MCAGCC), 29 Palms, California. The goal of LeatherNet was to provide a naval presence in Synthetic Theater of War 1997 (STOW 97). LeatherNet is a system of software tools that together create a DIS-compatible, virtual simulation. These tools consists of CommandTalk, CommandVu, and Marine Corps Semi-Automated Forces (MCSAF) [12]. Both LeatherNet and the VST possess unique components that, if merged together, could provide a more viable tool for the visualization of and the interaction with simulations.

3.3 Army Battle Command System

The Army Battle Command System (ABCS) is comprised of the Army Global Command and Control System (AGCCS), the Army Tactical Command and Control System (ATCCS) and the Force XXI Battle Command, Brigade-and-Below (FBCB2) System. "ABCS is the integration of command and control systems found at all echelons" [13]. The ATCCS is comprised of five tactical Command and Control (C2) systems: Maneuver Control System (MCS), Advanced Field Artillery Tactical Data System (AFATDS), All Source Analysis System (ASAS), Forward Area Air Defense Command Control and Intelligence (FAADC2I) System, and Combat Service Support Control System (CSSCS). Future work on the VST could include integration with MCS to take advantage of its unique capabilities [13].

3.4 Optional Interface

Though it provides an intuitive means for interaction between the user and the VST, the VST input interface, a stylus/tracking and voice recognition system, has certain drawbacks. The voice recognition system currently used in the VST does not provide the level of quick and robust recognition most likely required by the intended user group of military commanders. The stylus/tracking hardware does not provide a high level of accuracy when generating the coordinate information required to position the 3D cursor. One way of overcoming these deficiencies would be to use an alternative interface, such as a touchscreen or touchpad with graphics display. A touchpad may not be as intuitive to use as the current input interface, but it would allow discrete control of the same functions available in the current input interface.

4. CONCLUSION

The VST is a series of software tools meant to supplement current and future Army C4I systems. With the aid of an innovative 3D view of the battlefield and an intuitive interactive interface and the use of a horizontally oriented rear-projection display system, the VST can help a commander manage the current battle and prepare for the future battle. The VST allows a commander and staff to better manage information about the current battle and could provide the commander an interface into a simulation. This simulation would allow the commander and his staff to conduct COA development and analysis quickly and accurately. The VST could help commanders on future battlefields stay inside the enemy's decision loop, making U.S. combat formations more efficient and effective.

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APPENDIX A:
RELATED EFFORTS

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Related Efforts

1. The Responsive Workbench
    GMD - German National Research Center for Information Technology
    Stanford University

2. ImmersaDesk
    Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago
    152 Computing Applications Building
    605 East Springfield Avenue
    Champaign, IL 61820

3. Immersive Workbench
    Fakespace, Inc.
    4085 Campbell Avenue
    Menlo Park, CA 94025
    415-688-1940

4. Sea Dragon
    Naval Research Laboratory
    ATTN: Larry Rosenbloom
    Code 5580
    Washington, DC 20375-5337

5. Mirage
    Institute for Simulation and Technology
    University of Central Florida
    ATTN: Scott Smith
    3280 Progress Drive
    Orlando, FL 32826

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APPENDIX B:

HARDWARE AND SOFTWARE COMPONENTS

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HARDWARE

3600 Module Projector, AmPro Corporation
67" Diagonal Light Table, AmPro Corporation
Audio Equipment Including Headset and Preamplifier (1), BBN Hark Systems Corp.
CrystalEyes Stereo Eyewear (5), Stereographics
CyberGlove, Virtual Technologies
EPRO Emitters (3), Stereographics
Fastrak Tracking System, Polhemus, Inc.
Flat Panel Display (3), PixelVision
GesturePlus System, Virtual Technologies
Indigo2 High Impact Computer (1), Silicon Graphics, Inc.
Indigo2 Maximum Impact Computer (1), Silicon Graphics, Inc.
Onyx RealityEngine2 Computer System (2), Silicon Graphics, Inc.
Stylus with 20' Cable, Virtual Research Systems, Inc.

SOFTWARE

BBN Hark Developer's Toolkit, BBN Hark Systems Corporation
BBN Hark Workstation Recognizer, BBN Hark Systems Corporation
ModSAF, DMSTTIAC Service Center Institute for Simulation and Training,
    University of Central Florida
NPSNET, Naval Postgraduate School
VirtualHand Software Library, Virtual Technologies

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APPENDIX C:

PROJECTION TABLE SCHEMATIC AND SPECIFICATIONS

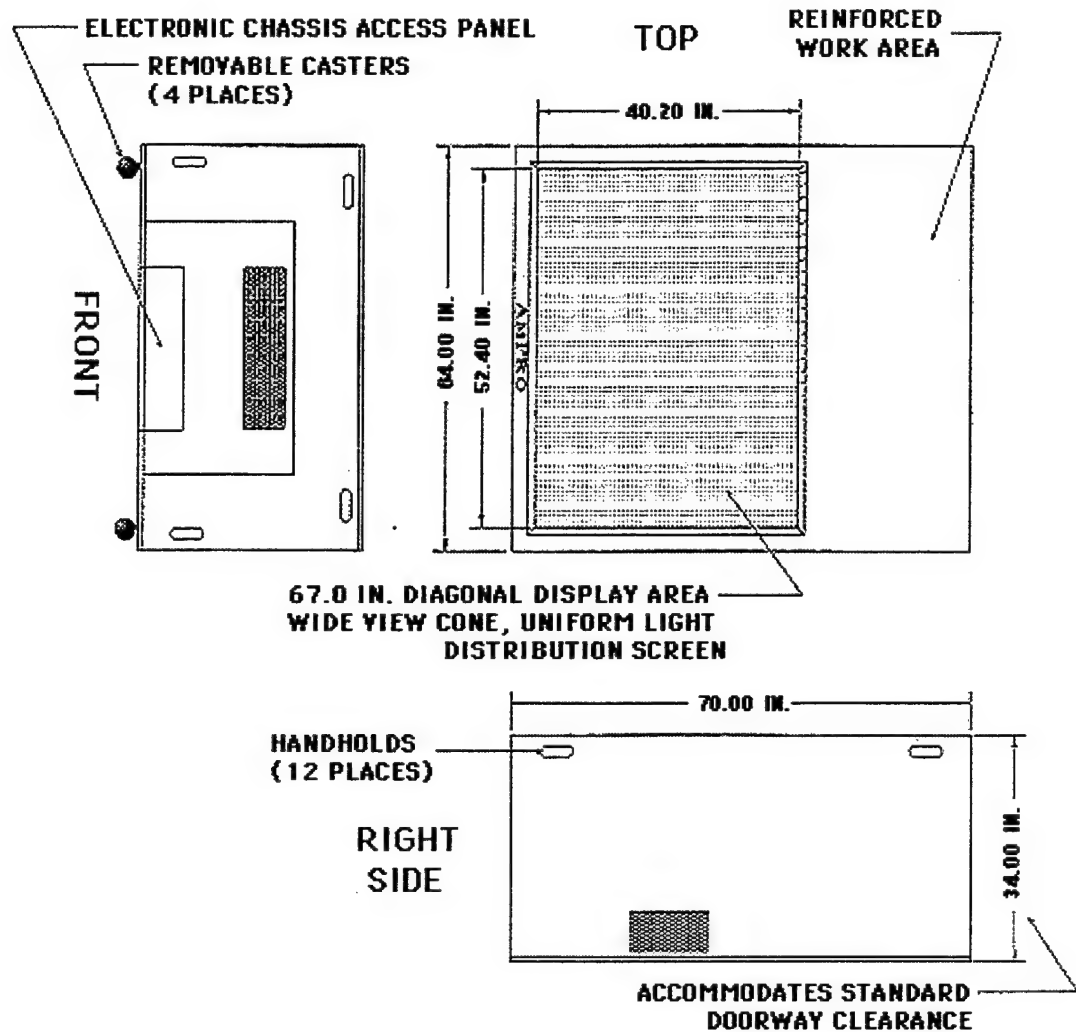INTENTIONALLY LEFT BLANK

AMPRO P/N 69682 Projection Table Schematic

ELECTRONIC CHASSIS ACCESS PANEL   TOP   REINFORCED WORK AREA

REMOVABLE CASTERS
(4 PLACES)

40.20 IN.

FRONT

64.00 IN.

52.40 IN.

AMPRO

67.0 IN. DIAGONAL DISPLAY AREA
WIDE VIEW CONE, UNIFORM LIGHT
DISTRIBUTION SCREEN

70.00 IN.

HANDHOLDS
(12 PLACES)

RIGHT
SIDE

34.00 IN.

ACCOMMODATES STANDARD
DOORWAY CLEARANCE

Figure C-1. Projection Table Schematic.

21

AMPRO P/N 69682 Projection Table Specifications

Cabinet
- ruggedized, Nevamar Laminate covering
- adjustable leveling feet
- fits through standard 36" doorway
- 2 storage compartments

Screen
- 1.3 gain, high contrast, coated, custom available
- 67" diagonal viewing area, 1/2" thick

Brightness
- more than 70 foot lamberts (peak white)

Resolution
- compatible with computer displays of 2500 x 2000 pixels
  - MTF (modulation depth) > 15% in horizontal and vertical resolution at 1280 x1024 pixels

Video Bandwidth
- electronic bandwidth of 100 Mhz

Input Source Compatibility
- horizontal autolock of 15-105 kHz for compatibility with computer workstations
- vertical autolock of 40-150 Hz
- horizontal retrace better than 2.8 usec
- vertical retrace less than 400 usec
- auto detection of positive or negative H and V sync
- auto detection of sync on green, composite, or separate H and V sync
- remote selectable clamp on sync tip or back porch sync

Picture Quality
- precise, continuously variable CRT-to-lens adjustment (Scheimpflug) ensures picture focus top-to-bottom and edge-to-edge
- selectable preset color temperatures of 3600°, 6500° and 9300° K and custom temperature
- remote control of RGB black level and gain for precise colorimetry adjustment
- liquid cooled 8-inch electromagnetic focus advanced electron gun technology that maintains high resolution at peak brightness
- liquid coupled HD-117-12 lenses with an optical resolution 10 lp/mm
- full convergence on green

Facilitated Setup
- built in menu-driven setup procedures that guide the user through the process with on-screen notations and visual cues on the section of the image being adjusted
- direct access to all setup functions for quick touch-up by experienced users
- Automatic Convergence Scaling (ACS) between established sources to reduce setup time

Certifications
- Underwriters Laboratory 1950 (pending)
- FCC Class A
- Department of Human Health and Services (DHHS) X-radiation under CFR Title 21, Chapter I, Subchapter J
- CISPR 22 Class A, Radio Frequency, Conducted and Radiated

Input Modules
- RGsB/HV
- dual stereo amplifiers with speakers

Operator Controls
- remote control with illuminated keypad and LCD display for complete projector control
- recall within 800 msec of each of up to 50 stored source parameters
- Auto Search Mode for Automatic source selection within a horizontal accuracy of ± 10 Hz and vertical accuracy of ± 1 Hz
- RS232 communications for computer control or networking for separate or global control of multiple projectors

Diagnostics
- 57 diagnostic and operating messages available on remote control LCD display
- on screen display of horizontal and vertical frequencies active channel parameter and diagnostics
- elapsed operating time and standby time clock display
- internal microprocessor monitoring of system status
- selectable 5-day or 7-day timer for timed operation

Power
- 800 watts maximum power consumption; 110/220 VAC, 50/60 Hz

Weight
- 450 lbs, 650 lbs shipping weight

Inc. Accessories
- illuminated remote control with 32 character backlit LCD display and 25 ft. (7.6 m) cable
- AC power cord
- Operation Manual

APPENDIX D:
VIRTUAL SAND TABLE COMMAND LIST

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Virtual Sand Table Command List

Commands with '#' after them put VSTLink and NPSNET into a new mode that continues until the termination command. Generally, other "nonmodal" commands still function normally, regardless of the system's mode.

Map Control Commands:

PAN { Left, Right, Up, Down }
- moves the view of the world in the direction indicated

ZOOM { In, Out, Up, Down }
- zooms the map in (closer) or out (farther)

ROTATE { Left, Right, Clockwise, Counterclockwise }
- rotates the view of the world 90° in the direction indicated

FASTER / SLOWER
- increases or decreases the speed of PANing or ZOOMing

POINTING DEVICE GLOVE
- changes the active pointing device to the dataglove

POINTING DEVICE STYLUS
- changes the active pointing device to the stylus

LOCATION ON / LOCATION OFF
- toggles on or off the location information in the NPSNET window

INFORMATION ON / INFORMATION OFF
- toggles on or off the simulation information block in the NPSNET
  window

RADAR TOGGLE
- cycles through each of the six HUD modes

Tethering Commands (currently, not all commands are fully implemented):

TETHER TO VEHICLE #
- sends a data PDU to all SLAVE NPSNETs to tether to the indicated
  vehicle

ATTACH TO VEHICLE #
- sends a data PDU to all SLAVE NPSNETs to attach to the indicated
  vehicle

FREE FROM VEHICLE
- sends a data PDU to all SLAVE NPSNETs to unattach or untether from
  any vehicles to which they are currently attached or tethered

CAMERA { Left, Right, Clockwise, Counterclockwise }
- rotates the camera of a tethered or attached vehicle, in 15° increments, to
  allow the user to get different views of the terrain

CAMERA { Down, Up }
 - moves the camera of a tethered or attached vehicle up or down

CAMERA HOME
 - puts the camera back in its starting position

Graphics Commands:

DRAW { Axis of Advance, Main Axis of Advance, Avenue of Approach, Main Avenue
 of Approach, Route, Alternate Route, Phase Line } #

 - the type of line can be preceded by a color: black (default), yellow, red,
  green, or blue

 - this command puts NPSNET and VSTLink into the line drawing mode
  until the command DONE is spoken

 - it is possible for a user to start a second modal command without
  terminating the current mode (e.g., start drawing a phase line before
  terminating the drawing of an axis of advance)

DRAW { Coordination Point, Coordinating Point, Contact Point, Control Point,
 Decision Point, Orientation Point, Entry Point, Exit Point, Initial Point, En
 Route Rally Point, En Route Point, Target Point, Rendezvous Point, Egress
 Point, or Penetration Point } #

 - the type of point can be preceded by a color: black (default), yellow, red,
  green, or blue

 - this command puts NPSNET and VSTLink into the point drawing mode
  until the command DONE is spoken

 - it is possible for a user to start a second modal command without
  terminating the current mode (e.g., start drawing a phase line before
  terminating the drawing of an axis of advance)

HUD Commands:

LOCATION { On, Off }
 - turns on or off a block of text in the bottom right corner with information
  about the location of the Napoleon vehicle and the cursor (equivalent to
  pressing the F2 key)

INFORMATION { On, Off }
 - turns on or off a block of text with information about the current mode,
  snapping distance, etc. (equivalent to pressing the F3 key)

TOGGLE RADAR or RADAR TOGGLE
 - cycles through radar modes (equivalent to pressing the F4 key)

Miscellaneous Display Commands:

TOGGLE STEREO or STEREO TOGGLE
>- turns on or off stereo mode (equivalent of pressing the F8 key)

TOGGLE CONTROL MEASURES
>- turns on or off the display of persistent objects like line (equivalent of pressing the 'o' key)

TOGGLE UNIT or UNIT TOGGLE
>- turns on or off the display of unit icons (equivalent of pressing the 'U' key)

UNIT PANIC BUTTON
>- resets display position of unit symbols (equivalent of pressing the 'V' key)

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LIST OF ACRONYMS

2D	Two-Dimensional
3D	Three-Dimensional
ABCS	Army Battle Command System
AFATDS	Advanced Field Artillery Tactical Data System
AGCCS	Army Global Command and Control System
API	Application Program Interface
ARDEC	U.S. Army Armament Research, Development, and Engineering Center
ASAS	All Source Analysis System
ATCCS	Army Tactical Command and Control System
C2	Command and Control
C4I	Command, Control, Communications, Computers, and Intelligence
CIP	Combat Information Processor
COA	Course of Action
CSSCS	Combat Service Support Control System
DARPA	Defense Advanced Research Projects Agency
DIS	Distributed Interactive Simulation
FAADC2I	Forward Area Air Defense Command Control and Intelligence
FBCB2	Force XXI Battle Command, Brigade-and-Below
HUD	Heads-Up Display
IR	Infrared
LCD	Liquid Crystal Display
MCAGCC	Marine Corps Air Ground Combat Center
MCO	Multichannel Option
MCS	Maneuver Control System
MCSAF	Marine Corps Semi-Automated Forces

ModSAF   Modular Semi-Automated Forces

NPS   Naval Postgraduate School

PDU   Protocol Data Unit

POP   Persistent Object Protocol

SGI   Silicon Graphics, Inc.

STOW   Synthetic Theater of War

TCP/IP   Transmission Control Protocol/Internet Protocol

TRADOC U.S. Army Training and Doctrine Command

VE   Virtual Environment

VGIS   Virtual Geographic Information System

VST   Virtual Sand Table

31

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REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project(0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE August 1997	3. REPORT TYPE AND DATES COVERED Final, Jan - Oct 96

4. TITLE AND SUBTITLE

The Virtual Sand Table

5. FUNDING NUMBERS

6U24D0

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
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Aberdeen Proving Ground, MD 21005-5067

8. PERFORMING ORGANIZATION REPORT NUMBER

ARL-TR-1456

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Virtual Sand Table (VST) is a series of software tools designed to help commanders better manage their battle space on a highly digitized battlefield identified by the U.S. Army as its near-team vision of future battle. The VST will assist commanders and their staffs in conducting the current battle and in preparing for the future battle. The VST provides an innovative way to visualize the battlefield from a unique and realistic perspective.

14. SUBJECT TERMS

virtual sand table, simulation, visualization, command, control, virtual .

15. NUMBER OF PAGES

32

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

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